KTEV
Kaons at the Tevatron

UNIVERSITY of VIRGINIA

Plans for $K_L \to \pi^0\pi^0\mu^+\mu^-$

David G. Phillips II

KTeV Collaboration Meeting

May 13, 2006

Table of Contents

1) Introduction and Motivation for Studying

   $K_L \to \pi^0\pi^0\mu^+\mu^-$ (note: have not yet considered $K_L \to \pi^0\mu^+\mu^-$)

2) Previous Studies

   ~ summary of theorist brainstorming

   ~ quick overview of previous KTeV work

3) Plan for Proceeding -> Analysis Strategy!

Introduction & Motivation

- switched thesis topic from $K_L \to \gamma\gamma$ to $K_L \to \pi^0\pi^0\mu^+\mu^-$ in March 2006.
  (note: have collected data & papers for $K_L \to \pi^0\mu^+\mu^-$)

- preliminary KTeV study on $K_L \to \pi^0\pi^0\mu^+\mu^-$ performed by Leo Bellantoni
  (see December 2005 writeup.)

- currently, there's no published calculation inside the Standard Model for
  $Br(K_L \to \pi^0\pi^0\mu^+\mu^-)$, although the decay is possible via γ^*.

- however, HyperCP reports a *'potential'* new neutral boson X^0 observed via
  $\Sigma^+ \to pX^0 \to p\mu^+\mu^-$. They determined the following branching ratios:

$$Br(\Sigma^+ \to p\mu^+\mu^-) = (8.6^{+6.6}_{-5.4}(stat) \pm 5.5(syst))\, x10^{-8},\ Br(\Sigma^+ \to pX^0 \to p\mu^+\mu^-) = (3.1^{+2.4}_{-1.9}(stat) \pm 1.5(syst))\, x10^{-8}$$

- two groups (Valencia *et al*. and Deshpande *et al*.) have recently
  computed $Br(K_L \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-)$ in a phenomenological fashion.

Previous Studies

~Theorist Brainstorming~

- Valencia *et al.* and Deshpande *et al.* calculate *Br*($K_L \to \pi^0\pi^0 X^0 \to \pi^0\pi^0\mu^+\mu^-$) following observations made by HyperCP; that is, they assume that the X^0's have small widths, are short lived and do not interact strongly.

- Deshpande *et al.* estimates contraints on scalar and pseudoscalar X^0's.

- finding that pseudoscalar couplings have the largest contribution, they evaluate the branching ratio as:

$$Br(K_L \to \pi^0\pi^0 X^0 \to \pi^0\pi^0\mu^+\mu^-) = 8.02\, x10^{-9} \qquad (\textit{Deshpande et al.}, 2005)$$

- Valencia *et al.* take things a step further and consider scalar, pseudoscalar, vector and axial vector particle possibilities for the X^0 state.

- the decay $K^+ \to \pi^+\mu^+\mu^-$ places serious constraints on scalar and vector particle possibilities. The branching ratio for $K^+ \to \pi^+\mu^+\mu^-$ has been measured to be:

$$Br[K^+ \to \pi^+\mu^+\mu^-] = (8.1 \pm 1.4)\, x10^{-8} \qquad (PDG, 2004)$$

- combining the upper result with constraints on scalar and vector couplings, *Valencia et al.* calculates theoretical upper limits on $Br(\Sigma^+ \to pX^0 \to p\mu^+\mu^-)$:

$$Br(\Sigma^+ \to pX^0{}_S \to p\mu^+\mu^-) < 6\, x10^{-11}, \quad Br(\Sigma^+ \to pX^0{}_V \to p\mu^+\mu^-) < 3\, x10^{-11}$$

- the above upper limits effectively eliminate both scalar and vector particles as explanations of the HyperCP result.

- they then use existing constraints on pseudoscalar or axial vector X^0's to predict the pseudoscalar and axial vector X^0 contributions to the $K_L \to \pi^0\pi^0\mu^+\mu^-$ decay mode:

$$Br(K_L \to \pi^0\pi^0 X^0{}_P \to \pi^0\pi^0\mu^+\mu^-) = \left(8.3^{+7.5}_{-6.6}\right) x10^{-9}$$

(*Valencia et al.*, 2005)

$$Br(K_L \to \pi^0\pi^0 X^0{}_A \to \pi^0\pi^0\mu^+\mu^-) = \left(1.0^{+0.9}_{-0.8}\right) x10^{-10}$$

- there is no current *experimental* upper limit on $K_L \to \pi^0\pi^0\mu^+\mu^-$ or $K_L \to \pi^0\pi^0 X^0 \to \pi^0\pi^0\mu^+\mu^-$.

Previous Studies

~Leo's Bag O' Tricks~

- the data used in Leo's study was from trigger 5 of the 1997 KTeV E799 run.
- results from his analysis include:

  ~acceptance of 2.73% $\rightarrow$ single event sensitivity of $1.4\,x10^{-10}$

  ~signal of less than 2.3 events

  90% C.L. $\rightarrow$

  ~partial width for 'new physics' estimated to be $< 4.0\,x10^{-24}\,MeV$

  ~*dismissal* of the claim of a new neutral boson by HyperCP.

- the aforementioned analysis does however have some potential shortcomings that need to be addressed, such as the following:

  ~identification and estimation of background.

  ~selection and completion of a normalization analysis.

  ~systematics in the sensitivity!

  ~usage of a constant matrix element in the $K_L \rightarrow \pi^0\pi^0 X^0 \rightarrow \pi^0\pi^0\mu^+\mu^-$ MC generation.

$K_L \to \pi^0\pi^0 X^0 \to \pi^0\pi^0\mu^+\mu^-$ Analysis Strategy

-Data Selection-

- the data to be used in this study will be from trigger 5 of the 1997 (1999 later on) KTeV E799 run

- looks like Leo used the NZL tapes (001-066 for winter data, 067-130 for summer data) for his crunch...these comprise runs 8028-10978.

- some other decays available from trigger 5 are: $K_L \to \pi^0\pi^0\mu^+\mu^-$, $K_L \to \pi^0\mu^+\mu^-$ and $K_L \to \mu^+\mu^-\gamma\gamma$.

- still thinking about which *normalization* mode to choose for $K_L \to \pi^0\pi^0 X^0 \to \pi^0\pi^0\mu^+\mu^-$.

TRIG5[2MU-LD] =
GATE*2V*DC12*2MU3*PHVBAR1*2HCY_LOOSE*HCC_GE1

<-'97 def'n

2V = 2 hits in V view and 1 hit in V' view *OR* 2 hits in V' and 1 hit in V.

DC12 = at least 1 DCOR hit in each view of DC1 and DC2.

2MU3 = 2 or more hits in the X and Y views of MU3.

PHVBAR1: this is a veto on all RC's (except RC8), all SA's and the CIA. Specifically, this rejects events that deposit ≥ 500 MeVin the RC's and ≥ 400 MeV in the SA's and the CIA.

2HCY_LOOSE: 2+ hits in every y view of the drift chambers (by the hit counting module); however, a missing hit is allowed in the y view of chamber 1 *OR* chamber 2.

HCC_GE1: ≥ 1 hardware cluster.

Future Plans

- HyperCP uses a uniform matrix element for $\Sigma^+ \to pX^0 \to p\mu^+\mu^-$. This would not be advisable for $K_L \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-$ since the K_L decay is momentum dependent.

→ *must ensure that we use the correct matrix element in the MC generation!!!*

- luckily, *Deshpande et al.* gives the matrix element for $K_L \to \pi^+\pi^-X^0 \to \pi^+\pi^-\mu^+\mu^-$ (albeit for a pseudoscalar X^0)

- meanwhile, *Valencia et al.* provides the matrix element for the decay $K^0\mathbf{bar} \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-$ (for both pseudoscalar and axial vector X^0's)

- with the tools listed above, we should be able to construct a suitable matrix element for $K_L \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-$ and begin MC generation!

- in short, this analysis is being started from scratch and I will be analyzing the data *with the box closed* and with my own cuts.

- still need to decide on my *backgrounds*, then begin generating...the *background* would be at the edge of phase space.